

TRENTON FALLS HYDROELECTRIC STATION

On west bank of West Canada Creek along Trenton Falls Road,
1.25 miles north of New York Route 28

Trenton

Oneida County

New York

HAER No. NY-155

HAER
NY
33-TREN,
1-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD

National Park Service

Northeast Region

U.S. Custom House

200 Chestnut Street

Philadelphia, PA 19106

HISTORIC AMERICAN ENGINEERING RECORD

TRENTON FALLS HYDROELECTRIC STATION

HAER No. NY-155

HAER
NY
15-TREN
1-

Location: On west bank of West Canada Creek, along Trenton Falls Road from 1.25 to 2 miles north of New York Route 28

Trenton Falls
Oneida County
New York

USGS Quadrangle: Remsen, New York

UTM Coordinates: 18.487280.4791220 (powerhouses)

Dates of Construction

and Major Modifications: 1899-1901 (Old Powerhouse, dam, 7-foot pipeline)
1917-1921 (New Powerhouse, substation, 12-foot pipeline, high level intake)
1931 (pipeline and dam intake reconstructions)
1983-1985 (replacement of 7- and 12-foot pipelines with single 14-foot pipeline)
1987-1991 (dam repairs)

Contractors/Engineers:
(1899-1901)

General Contractor, Utica Electric Light & Power Company; Project engineers, George A. Brackenridge (supervising engineer) and J. W. Jenkins (chief engineer); Pumps, J. E. Morris Company, Philadelphia, PA, and William M. White (design consultant); Generators, General Electric Company, Schenectady, NY; Dam and Foundations, T. A. Gillespie Company, New York, NY; Pipelines, Warren-Burnham Company, Utica, NY; Crane, Reading Crane & Hoist Works, Reading, PA.

Contractors/Engineers:
(1917-1921)

General Contractor, U.S. Structural Company, Dayton, OH; Project Engineers, Byron S. White (supervising engineer); Thomas E. Murray, George A. Orrok, Philip Torchie (consulting engineers); Turbines, Platt Iron Works, Dayton, OH (1917-1918); Hooven, Owens, Rentschler, Company, Hamilton, OH (1921); Generators, Westinghouse Electric & Manufacturing Company; Pipelines, Chicago Bridge & Iron Works, Chicago, IL (steel); Washington Pipe & Foundry Company, Tacoma, WA (wood); Crane, Cleveland Crane and Engineering Company.

Contractors, 1931

Pipeline, Farrer & Trefts, Buffalo, NY; Gate Hoists, Limitorque Corporation, Williamstown, MA

Present owner:

Niagara Mohawk Power Corporation
300 Erie Boulevard West
Syracuse, NY 13202

TRENTON FALLS HYDROELECTRIC STATION
HAER No. NY-155 (Page 2)

Present use: In operation; turbine-generator units 1-4 out of service

Significance: Strongly influenced by the earliest Niagara hydroelectric project, the 1901 Trenton Falls Station was installed in a spectacular gorge and was probably the highest-head non-contemporary plant in the eastern United States. A distinctly transitional station, Trenton Falls combined European-style turbines which soon proved outmoded with prescient, long-lived choices in electric generating and control equipment. The new powerhouse, added to the old one in 1919, reflected a generation of rapid development in hydroelectric station design and equipment. Together, the two powerhouses survive as a powerful example of technological and architectural change over a short period of time. The largely-original 56-foot-high dam evokes the regional magnitude of the station when first built.

Project

Information:

Trenton Falls Station is eligible for listing on the National Register of Historic Places. Niagara Mohawk Power Corporation proposed station modifications in the 1970s. As a result of project review by the Advisory Council on Historic Preservation, the New York State Historic Preservation Officer, and the Federal Energy Regulatory Commission (FERC), Niagara Mohawk will remove three of the four original turbine-generator units and stabilize powerhouse foundations. HAER documentation of the station, required by revised Article 35 of FERC license 2701 prior to such actions, was conducted from February to August 1993.

Project manager and historian:

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Part I - Historical Information*

Trenton Falls Gorge, Resort Development, and Hydropower Opportunities

Trenton Falls station was built at the lower end of a spectacular gorge or chasm on West Canada Creek, a stream fed by a series of lakes in the southwestern Adirondacks about forty miles northeast of the gorge. The creek, which once flowed southwest into the Mohawk River through what is now Nine Mile Creek, was diverted sharply to the south and southeast at the present village of Prospect by a glacial moraine and now reaches the Mohawk at Herkimer. In reaching the Mohawk, enormous amounts of glacial meltwater passing through the diverted creek cut through sedimentary rocks to create the gorge. West Canada Creek's drainage basin above the gorge is about 375 square miles, with a mean annual flow estimated early in the 20th century at 1175 cubic feet per second (cfs). Until the hydropower development, the three-mile-long chasm was a series of eight falls which dropped about 330 feet between the villages of Prospect and Trenton Falls. The Prospect Falls were the uppermost, with the others stretching over a 1.5-mile distance beginning at the present Trenton Falls dam pond, which covers the 20-to-30-foot drop of the Rocky Heart and Cascades of the Alhambra falls. The last five falls drop 171 feet, past Village Falls below the present powerhouses. Trenton Chasm is 50-to-200 feet deep and very steep. The 30-to-200-foot wide bottom has broad sheets of rock, pocked with numerous potholes created by tumbling, whirling boulders once suspended in the cascading creek. Most of the chasm consists of Trenton limestone, a 300-foot-thick series of strata of varying thickness and hardness. The harder upper strata were quarried for building stone in the 19th century, while the softer, more friable deposits were used to make lime for mortar before the advent of Portland cement.¹

The chasm's relative remoteness and magnitude restricted use of this considerable hydropower resource until the end of the 19th century, but allowed the splendor of the gorge to become a major tourist attraction. There was no White settlement in this vicinity until a decade after the Revolution. By the early 1790s, settlement extending north from Utica included a village at Barneveld west of the gorge, and a sawmill on the east side of the gorge at Mill Dam Falls below the present hydroelectric project dam. Improved transportation links with the Mohawk Valley, beginning c1803 with a road to Utica about twelve miles away, stimulated local agrarian commerce. By the early 1820s, there were limestone quarries on both sides of the gorge, and a sawmill and gristmill on the west side of Village Falls. These mills became the focus of the small village of Trenton Falls.²

* Capitalized, undated references are to photographs in this documentation.

Cycles of transportation improvements paced the rise and fall of this village as a tourist destination. The rapid emergence of east-west routes in the Mohawk Valley and westward prompted development of the chasm as a destination for artists and other scene-seeking travelers. Between 1810-36, stagecoach-travelled roads, the Erie Canal, and a series of railroads linked Utica with Albany and Buffalo.³ The route from Manhattan or Boston across New York to Niagara Falls was part of a Grand Tour by 1830. A decade earlier, the road north from Utica was sufficient to start a small traffic in locally-guided tours of Trenton Chasm, with the beginnings of a network of ladders or stairs. In 1822, the Rev. John Sherman purchased part of the chasm and built a small "Rural Resort" immediately west of the present powerhouse and transformer yard. Sherman had migrated to Barneveld from Connecticut in 1806 to lead a Unitarian congregation, but soon sought other means such as schoolteaching to make a living. With financial backing from a former mayor of New York City, Sherman enlarged his Resort 1826 and further developed the attraction with stairs and a small refreshment stand. Although he died in 1828, his resort soon emerged as one of America's premier attractions under the management of his son-in-law Michael Moore. Completion of the Northern Plank Road from Utica to Remsen in 1848 spurred Moore to establish a link to the hotel, and to enlarge it to 100 rooms in 1851, making it the largest hotel in New York State north of Utica. He hosted some 7400 visitors the next year, and continued to prosper when the Black River and Utica Railroad opened in 1855, with a Trenton Falls Depot established a short distance from the village in 1856. Moore's success was a boon to the village, and led to a number of other smaller hotels in the vicinity. The status of Moore's Hotel as a national destination probably peaked in 1863, when Secretary of State William Seward hosted a number of European ministers during diplomatic efforts to isolate the Confederacy.⁴

After 1880, additional railroad construction into the Adirondacks made that region and the St. Lawrence River's Thousand Islands widely accessible for the first time, and the resulting burst of tourism and recreational development soon diminished the market for Trenton Chasm. The Mohawk and Malone Railroad, completed from Herkimer to Remsen in 1893, crossed the gorge between the Alhambra and Mill Dam Falls, just south of the later dam.⁵ The gorge became more a stop-over or trainscape than a resort for extended stays. By 1896, when entrepreneurs and engineers first looked at Trenton Chasm as a source of hydroelectric rather than recreational income, Moore's widow and others in the local tourist business were prepared to end two generations of resort life.⁵

* The Mohawk and Malone ceased passenger traffic in 1934, and abandoned the bridge by 1938; the Black River Railway demolished the Trenton Falls Depot by this time. To meet World War II demands for scrap metal, the tracks and bridge over Trenton Chasm were removed, leaving two large stone piers (Pratt and Pratt 1978: 20).

The First Phase of Trenton Falls Hydroelectric Development, 1899-1901

Initial Planning, Designers, and Summary of Site Arrangements

Detailed planning for the Trenton Falls station began in the late 1890s, during a period of intense development in hydroelectric power generation and transmission development, following the 1893 opening of the first powerhouse at Niagara Falls, New York. The Niagara project, completed by the Cataract Construction Company, was pivotal because it demonstrated to Eastern United States financial interests "...the possibilities of large-scale production and long-distance transmission of electrical energy and the special value of alternating current..." for tapping the potential of hydropower sites far from urban or industrial areas.⁶ Cataract Construction, formed in 1889 to finance and construct projects of the Niagara River Hydraulic Tunnel, Power and Sewer Company, had the backing of major American financiers led by J. Pierpont Morgan. Their success at Niagara stimulated smaller-scale entrepreneurs such as those at Utica who built the Trenton Falls station.⁷

Utica had a significant concentration of textile plants beginning early in the 19th century, and by 1880 steam-powered cotton and woolen mills were still the major industries for a metropolitan population of some 34,000.⁸ Local private firms began making steam-generated electricity for lighting in 1881. By 1890, demand for lighting and electric railroad power increased beyond local station capabilities, stimulating new investors to enter the utility arena. In that year, there were three Utica power-making companies: Equitable Gas and Electric Company (a merger of three earlier firms); Utica Electrical Manufacturing and Supply Company; and Utica Electric Light Company. The latter two firms were the newest, and after the first Niagara powerhouse opened they each began investigating hydroelectric development at Trenton Chasm.⁹

Others had the same idea, and by 1899 at least five groups or organizations were presenting plans or leasing water rights in the famous gorge. In addition to the two Utica utilities, civil engineer J.M. Jenkins -- one of the earliest observers of the chasm's power potential -- and Hawley Pettibone were leasing water rights from the Moores and others.¹⁰ The Niagara Falls Hydraulic Power and Manufacturing Company, a purveyor of hydromechanical power unrelated to the large Niagara hydroelectric project, began generating and distributing electricity at Niagara in 1894, and by 1896 had developed a plan to tap Trenton Chasm for supply of power to Utica and to future factories in the gorge area.¹¹ The last and most important entrant in the competition for gorge power was the Trenton Falls Electric Light and Power Company, organized in June 1899 by M. Jesse Brayton, H.M. Schench, and H.B. Sweet to supply up-country rather than Utica markets. None of the aspirants had enough capital to develop the chasm alone. Trenton Falls Electric managers soon succeeded in merging all competing interests except those from Niagara Falls Hydraulic Power, creating the Utica Electric Light and Power Company (UELPC). The water rights secured by Jenkins and Pettibone, which included an option to purchase the Moore hotel and land, were crucial to development. Wallace G. Phelps, who purchased Jenkins' and Pettibone's interests shortly before the merger, became a founding UELPC director.¹²

Jenkins remained involved as chief engineer of the project, but UELF retained William A. Brackenridge, former chief engineer of the Cataract Construction Company during the first Niagara project, as supervising engineer. The earliest project drawings suggest he was first hired by Trenton Falls Electric Light and Power Company prior to the merger creating UELF.¹³ Other than the plans prepared under his name, few details of the relative design roles of Brackenridge or others have emerged in research for this documentation. Other Niagara project builders, presumably introduced by Brackenridge, included Harry Hagaman, who supervised erection of electrical equipment at Trenton Falls, and the I. P. Morris Company, which made similar turbines for both projects.¹⁴

Although the Niagara influences on the first phase of Trenton Falls construction were strong, as discussed below, J.W. Jenkins' early surveys in the gorge probably framed some of the basic decisions made in capturing this tremendous hydropower resource. There were three major components at the Trenton Falls project, which defined all subsequent modifications made to the complex:

- a concrete gravity dam with auxiliary spillway and headworks, about 650 feet above Mill Dam Falls, designed for future pipeline additions;

- nearly 4000 linear feet of 7-foot-diameter pipeline running along the west side of the creek to a point on the bluff just east of the Moore Hotel;

- a powerhouse at the bottom of the gorge, 100 feet below the end of the pipeline, with four 1000-kw vertical-shaft turbine-generator units.

The 56-foot-high dam, located and largely designed by June 1899, added 52 feet of head to the 216 feet between the foot of the Cascades of the Alhambra falls and the foot of Sherman Falls. In 1899, this was the highest-head hydroelectric project in the eastern United States, with nearly twice the head of the first Niagara plant.¹⁵ Although their available flow was nothing like that of the Niagara River, the scale of their project probably led the Trenton Falls developers to hire Brackenridge, to assure themselves and their investors of success.

The Context of Trenton Falls Turbine and Electrical Design Decisions

Selection of turbine design and systems of power generation and transmission proceeded independently during Niagara project planning. This dichotomy persisted through the first phase of construction at Trenton Falls, which was strongly influenced by Niagara design decisions and results. The engineers and contractors involved in the 1891-95 Niagara construction who worked on the Trenton Falls project 1899-1901 were probably responsible for the striking contrast at the later project between prescient electrical choices and outmoded hydropower designs.

Hydroelectrical generation began to emerge c1885 as an offshoot of the then-dominant hydromechanical power transmission systems of all factories, steam or water, of the period. Before completion of the Niagara project, there was great uncertainty over the best means to distribute power over a distance of several miles from the point of production of the power. The proposals considered for Niagara varied widely, including compressed air as used in Paris, pressurized water as used on the docks in Great Britain, direct current electricity and finally alternating current electricity. The choices were not at that time obvious. Hydroelectricity might have emerged as the clear choice earlier had the proposals focussed more on western United States than European examples. Mining and processing companies in the Rocky Mountains and Sierra Nevada encountered severe energy problems of a type not easily overcome by any system other than electrical transmission, and installed many alternating current systems in the 100-1000 kilowatt range on heads of over 100 feet beginning c1890.¹⁶

While the Niagara project resolved many basic generation and transmission issues on large new scale with advanced technology, "...several elements of its hydraulic, mechanical and electrical systems proved impractical and were never used again."¹⁷ Many Niagara choices in hydropower and electrical equipment were already obsolete when Trenton Falls planning began.

Turbine Selection

Summary of Turbine Types

Water turbines or wheels fall into two broad categories: impulse turbines and reaction turbines. Impulse turbines derive power from the aiming of a free jet of water at a rotor or runner some distance away, capturing only the water's velocity. In contrast, reaction turbines use water pressure, with runners and gates or nozzles totally surrounded or immersed in the water column. The impulse wheel is best suited to higher heads, above about 100 feet, because water velocity at lower heads is too slow to capture effectively. By careful selection of runner type, the reaction turbine can work at heads between about 3 and 800 feet. Today, the choice between impulse and reaction turbines often depends on the desired runner/generator speed and unit capacity.

The most common type of impulse wheel is the Pelton, with the Girard and several others found far less frequently. Widely-used types of reaction turbine developed in the 19th century include the Francis (inward radial flow), mixed flow (a Francis variant), Jonval (axial flow), and Fournayron (outward radial flow); 20th-century variants include propeller types such as the Kaplan (all axial flows) and some hybrid types such as cross-flows.

Water controls, called gating or throttling, on the two major turbine categories vary dramatically. With the exception of the Girard, impulse turbines usually have rather simple nozzles, the more sophisticated having needle valves. Reaction turbines require far more complex gating to control effectively both water volume and the proper angle of water and runner blades. During the 19th century, turbine makers often tried a gate control type with a simple sliding cylindrical sleeve moving up or down to cover or uncover stationary guide vanes leading to the runner. The major drawback of this cylinder gate is that severe turbulence created at partial openings can ruin partial throttle performance. Despite widespread understanding of this problem by the 1880s, cylinder gates remained popular because of cost savings, and because on some types such as the Fournayron nothing else worked. On Francis and other more modern designs, a wicket gate throttling system is used with overlapping tangential gates arrayed at the periphery of the runner and linked so as to open or close together in unison. Register gate systems, seen on Jonval types, consist of a pair of congruent metal plates above the runner with identical sets of openings in each plate. The upper plate rotates, admitting water to the extent that the two sets of openings are in alignment or registered. Analogous domestic controls can be seen in containers of talc-type powder.

The Pelton is the simplest impulse type, basically consisting only of a nozzle and a wheel with double-spoon-like cups mounted radially on the wheel circumference. The Girard is a radial outward flow machine, with nozzles or gates mounted within the runner and aimed outward, and a rotor with cylindrical or segment blades attached approximately perpendicular to the circumference.

Verbal descriptions of reaction turbines are more difficult. The propeller is the simplest of the reaction turbines, consisting of propellers (similar to those used on boats) set in a pipe, with water flow parallel to the axis of rotation. Francis or mixed-flow types admit water radially along the casing circumference at right angles to the axis of rotation, and bend water flow downward for discharge nearly parallel to the axis. A Francis runner somewhat resembles the agitator in a modern clothes-washing machine. The Jonval combines some propeller and Francis features, with water flow parallel to the axis of rotation, but with stationary guide vanes above the rotor and a register mechanism to control flow. The Fournayron is somewhat like a Francis turbine turned inside out. Water enters through the middle, parallel to the axis, and turns ninety degrees to exit the runner radially. Typical Fournayron gating includes a cylinder mounted outside the runner. Runner geometry of Girards and hybrid cross-flows are very similar.

Niagara Turbine Choices Related to Trenton Falls Design

Swiss firms and consultants dominated the design of the first Niagara turbines, choosing units with vertical axes and vertically-mounted generators. The final design used a series of 5000 hp Fournayron double-runner outward-discharge type. These were then the largest electrical turbines in the world. Faesch and Pionard of Geneva did the drawings, but I. P. Morris Company of Philadelphia built the Fournayrons, largely to avoid freight, tariff, and patent problems.¹⁸ The Morris firm was established in 1828 and began building turbines in 1831, when it made seven Jonval wheels after the designs of Emile C. Geyelin for the City of Philadelphia Fairmont Water Works. Those machines were reported to have been in continuous duty operating pumps for the city's water supply for 60 years. Morris apparently always specialized in large machines, and usually built machines designed for a specific project rather than "stock pattern" or standard design units. In 1891, the firm became a division of the William Cramp and Sons Ship and Engine Building Company.¹⁹

The Fournayron was by the 1890s a relative dead end in water power hardware evolution. Introduced in France in 1827 by Benoit Fournayron, a turbine of this type was installed at St. Blaise, Switzerland in 1837 at the then-high head of 72 feet. Elwood Morris (apparently no direct connection to I. P. Morris) publicized the design in the United States c1839-42, and designed and built several small Fournayrons in the Philadelphia area. The firm of Robeson and Kilburn built several more in the Fall River, Massachusetts area. Uriah H. Boyden built a modified Fournayron of his own design from 1844 to 1848, and became the principal builder of Fournayrons in the United States, eventually making some as large as 700 horsepower at 33 feet of head. In 1847, James Francis, chief engineer for the Proprietors of Locks and Canals at Lowell, Massachusetts, apparently saw many of the limitations and problems inherent in the Fournayron outward discharge design, and developed the modified Howd inward-radial discharge machine that now bears his name. The Proprietors of Locks and Canals purchased the rights to build Boyden's designs the next year, and by 1858 installed 58 units of Francis' design, producing over 12,000 horsepower.²⁰ With changes and improvements by several other designers and engineers, the Francis became the dominant American turbine type by 1870 and in the world by 1910.

James Emerson, operator of the famous Holyoke Test Flume on the Connecticut River at Holyoke, Massachusetts, personally oversaw the testing of more different turbines than any other American. He had little but scorn for the Fournayron style in his report of 1894:

"In the purchase of this turbine, more ignorance is displayed than a well-wisher of his race likes to acknowledge lies dormant in the average business man. . . . [E]very intelligent turbine builder knows that of all wheels the outward discharge is the most difficult to get just right; also, that good part gate results are impossible with such discharge."²¹

Exactly how the Swiss convinced the Niagara Commission in 1892 that the Fournayron style was the best for their situation may never be known, but it may relate to their employment as a principal technical consultant Theodore Turrettini, an engineer from Geneva, the home town of Faesch and Piccard, the eventual winners of the turbine design. The options presented to the Niagara Committee included at least two that hindsight shows would have been much better than the route chosen. One, from Pelton Water Wheel Company of San Francisco, followed the established practice in Western American high head sites of using the tangential impulse turbine commonly called the Pelton Wheel. This type had an excellent reputation for efficiency and reliability gained in hydromechanical systems over the previous thirty years, and became dominant in high head sites (over 500 ft. of head) worldwide by 1915. The Pelton entry for Niagara proposed large multiple runner multiple nozzle units. These were rejected partially out of anxiety over the firm's ability to make large output units, and partially because the planners had already decided on generators at the top of the falls with long driveshafts coming up from vertical-axis units. Another Niagara entry, from the Stillwell-Sierce Company of Dayton, Ohio, included Francis turbines much like those installed by Stillwell-Sierce's successors, Platt Iron Works, at Trenton Falls in 1917.²²

The Fournayron turbines at Niagara Powerhouse No. 1 proved to be inefficient when operating at part gate, susceptible to clogging from trash, and excessively large and complex relative to their power output. They were replaced in 1910 with Francis units, similar to those installed at the second Niagara powerhouse (1900-1902).²³ The latter units were ordered shortly after four Fournayron units were ordered for the Trenton Falls development, as discussed below. In less than five years after the first Niagara installation, Fournayron hydroelectric performance had proven to be so limited that little original design work was ever put into this style again.

Design of The First Trenton Falls Turbines

The respective contributions of various hardware designers to Trenton Falls Powerhouse 1 remain somewhat obscure. Years later, William Monroe White was credited with design of the 1700-h.p. Fournayron units driving the main generators, and of the two 100-h.p. Girard turbines used to drive two exciter generators, under the overall supervision of George Brackenridge.²⁴ The historical context of the development, the close links between the first Niagara and Trenton Falls projects, and a small note at the bottom of one of the drawings sent to Utica Electric Power and Light by I. P. Morris stating "Traced PDK from Faesch and Piccard Print 3204," all indicate that White's work on at least the Fournayrons involved modification rather than completely original design.²⁵ Given the availability of the Niagara Falls Fournayron drawings in the shops and offices of I. P. Morris in Philadelphia, while they were building the Niagara units, and Brackenridge's close work with Faesch and Piccard representatives, it would have been easy for him and White to use the Swiss drawings of the turbine internal geometry as a basis for designing the Trenton Falls units. There are some significant differences between the Niagara and Trenton Falls Fournayrons, however, aside from the smaller output (1700 h.p. vs. 1000 h.p.) of the later units, the Niagara turbine had two runners on a common shaft, the water path and thus casing was somewhat simpler, problems of thrust compensation were partially alleviated by the balance between the two runners,

and the head was significantly lower at Niagara. Most of White's efforts probably went into the housings, throttle and governor interface of the Fourneyrons and their Porter-Allen governors, and the design of the Girard turbines for the exciter generators.

Even more so than the Fourneyron units, the Girard turbines represent a dead-end of a particularly European, Victorian nature. Invented in France by either a Madame de Girard in 1843, or by a L.D. Girard in 1863, the Girard type (also referred to as the "C" type) achieved limited success in Europe during the last third of the 19th century.²⁶ Girards were used in the highest head sites in Europe in preference to the American Pelton design, regarded by some as crude. Girards in the United States remained comparatively rare, although the Stillwell-Bierce and Smith-Vaile companies in Dayton, Ohio and their successor the Platt Iron Works (makers of two later Trenton Falls units) built several Girards with up to 1000 h.p. and even equipped them with draft tubes, rarely seen on impulse turbines.²⁷

European high-head turbine design followed a different path than seen in the "incubator period" of American designs c1850-80. Girards in Europe were installed at heads in excess of 1000 feet by c1900. Piccard, Pictet and Company of Geneva, successors to Faesch and Piccard, built units up to 2000 h.p. for use in the Alps and other high-head European installations. In contrast to the Trenton Falls Girards, with vertical shafts, most other early-20th century examples have horizontal shafts and simpler, lighter housings, often part steel fabrication rather than cast iron.²⁸

The Girard design suffered from inherent design requirements creating difficulty getting water cleanly away from the runner, resulting in low efficiency at certain flow rates and speeds, and runner pitting due to cavitation. These factors contributed to the commercial failure of Girards, which by perhaps World War I were not used in new American installations.²⁹ Girard turbines never enjoyed even the brief heyday of the Fourneyron in Northeastern textile mills, and American installations probably never exceeded a few dozen. Most hydroelectric and water power engineering books do not even mention the genre. At the time of the first Trenton Falls development, the Girard appeared to fill a perceived gap between the Francis, believed to be effective at no more than about 70 feet of head, and the Pelton wheel generally used at heads of over 500 feet. Hampered by very elaborate internal chutes in a register gate scheme, and the need for great precision in manufacture, the Girard simply provided too little for its cost. When the full potential of the high-head simple-flow Francis was realized, and the Cornell plant at Ithaca, New York confirmed the flexibility of Peltons to work at heads as low as 125 feet, there was little need for the Girard.

The Trenton Falls use of Girards is somewhat hard to fathom, except as a means to avoid patents and/or licensing fees. Since they mirror the water flow of the Fourneyrons (radially outward), they may have also emerged from the Faesch and Piccard designs available to Morris. By 1904, the two Girard exciter units at Trenton Falls were supplemented (or largely replaced) by one simple Pelton that is fully functional without repairs 90 years later.

There is no credible evidence for an evolutionary link between the Girard and Pelton designs, especially given the very complex operating mechanism of the Girard. The Trenton Falls developers apparently rejected what, with hindsight, appears as a more viable option for all turbine requirements, a proposal from the Pelton Waterwheel Company to equip the plant with an unknown number of multiple-runner Pelton units, each of 900-1200 h.p., with dual nozzles and nearly infinite throttling capability.³⁰ These were horizontal axis units similar to dozens Pelton had installed in the American West, many at far higher heads than Trenton Falls.

After their success at Niagara Station No. 1, Morris built the turbines for Station No. 2, this time following a Francis-style design of the Swiss Escher-Wyss and Company. It was during the transitional period from Station No. 1's Fourneyron machines to Station No. 2's Francis machines that Morris built the turbines for Trenton Falls. The Trenton Falls Fourneyrons were probably the last major units of this style built by Morris -- or anyone else -- before the firm concentrated on Francis turbines for high heads, and later, propeller turbines for low heads. The Trenton Falls Girards appear to have been the only ones Morris built; most of the few other American-built Girards were made by Platt Iron Works or their predecessors.

Electrical Generating and Transmission Systems

Beginning in 1889, when the Cataract Construction Company asked Thomas Edison to comment on electric power transmission at Niagara, there was intense American development and experimentation in electrical generation and transmission.³¹ Continuing through the earliest design period at Trenton Falls, construction of hydroelectric stations reflected the conflicting design philosophies of many engineers and manufacturers. More rapidly-evolving than turbines, electrical systems were in such flux that the Niagara design influences were very ephemeral. At Trenton Falls, designers made particularly modern choices which enhanced the first station's functional longevity.

The main issues in the 1890s electrical debates were what kind of electric power would be generated and how it would be transmitted. Edison's comments on Niagara began a fierce debate, first revolving on the question of whether the transmission should be in direct current or alternating current.³² The comparatively poor economics of the Edison three-wire DC system was soon apparent to project planners, who wisely leaned towards AC. A secondary debate ensued on how to generate and transmit AC power. One question involved single- vs multiple-phase generation and transmission. Niagara engineers chose 2-phase generation which simplified generator design and later adopted 3-phase for their transmission to Buffalo. Frequency of current was the next question: they chose 25 cycles per second (cps), favored by local industries and Buffalo traction lines.³³ Transmission voltage was pegged at 11,000 volts, high enough to secure economy without undue strain on insulators.

The Niagara project was the electrical wonder of the period but as an example it was not closely followed. Trenton Falls was developed just five years later, but it was five years of new development that rendered many of the electrical features of the Niagara stations obsolete. The four original main generators at Trenton Falls were wound for 3-phase, 60 cps, 2200 volt AC. Transformers stepped this up to 22,000 volts for the 12 mile transmission to Utica.³⁴ Hydroelectric projects in the western states had shown that large savings resulted in very high voltages, and Utica Electric Light & Power followed this lead.³⁵ As first built, Trenton Falls was essentially a modern station, reflecting the rapid consolidation and standardization seen in electrical manufacturing and engineering by 1900.³⁶

During a period of continuing new advances, station designers struggled to find the right combination of current, cycles and voltage for economic viability and a long life-span (Table 1). Sometimes they chose well in one area but not in others. One influence of the Niagara plants was a mixed standard of 25 cps for railways and power but 60 cps for lighting circuits.³⁷ Poor economics of providing two different frequencies led to a search for a single compromise figure, but there was little agreement and cycles varied from 25 to 120. Customers needing different frequencies were supplied by substations with rotating conversion machines.³⁸ By 1900, however, a consensus developed that 60 cps served most purposes; 25 cps plants built afterwards were usually dedicated to railway electrification.³⁹ While perhaps not including any "firsts" in the history of electrical engineering, the initial Trenton Falls design brought together at an early date many of the modern features seen over the next century. The choice of 3-phase, 60-cycle, high-voltage transmission, which has become the industry standard, undoubtedly contributed to the longevity of the station, and the survival there of the four General Electric umbrella type, 1000-kw main generators and two General Electric vertical, 85-kw exciters. By contrast, the Cataract Construction Company retained 25-cps 11,000-volt transmission for the 1904 Niagara Powerhouse No. 2, which lasted only sixty years.

Construction

Construction at Trenton Falls began in September 1899 at the dam, and proceeded on a round-the-clock basis with a work force of up to 700 men. Workers and engineers filled both resort hotels at the gorge, and a shanty town covered the former Moore Hotel picnic ground.⁴⁰ The dam, built by the T.A. Gillespie Company and discussed more fully in HAER No. NY-155-B, required some dynamiting for the main spillway and, especially, the auxiliary spillway where 30,000 cubic yards of rock were removed. Work at the dam took the lives of several men. From the dam, the Warren-Burnham Company built the 7-foot-diameter pipeline, with sections of iron-banded yellow pine and steel. The powerhouse was the last major component completed by WELP, and included removal of several thousand cubic yards of rock from the bottom and west side of the gorge.⁴¹ A steel-framed structure with a hipped red tile roof, faced with exterior Gouverneur marble and interior pressed brick, it presented a more embellished appearance than many contemporary hydroelectric plants, befitting its owners sense of the development's importance (see HAER No. NY-155-A).⁴² On April 18, 1901, the plant first transmitted power to Utica for traction, manufacturing, and lighting.⁴³

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Table 1. EXAMPLES OF ELECTRICAL GENERATION AND TRANSMISSION CHARACTERISTICS AT STATIONS BUILT 1897-1908

Site	Date	Transmission Volts(KV)	Miles	Phases	Cycles/ Second	Trans- former	Generator Orientation	Citation
Ogden, UT	1897	16.1	38	3	60	air	horizontal	American Electrician 1897
Mechanicville, NY	1898	12.0	18	3	38	none	horizontal	Engineering News 1898
Butta, NY	1898	15.0	20.6	3	60	air	horizontal	American Electrician 1898a
Dolgeville, NY	1898	10.0	8	2	60	oil	horizontal	American Electrician 1898b
St. Anthony Falls, MN	1898	12	10	3	38	air	horizontal	Street Railway Review 1899
Mt. Whitney, CA	1899	20.0	43	3	120	oil	horizontal	Engineering News 1899
Braqueville Falls MA	1900	38.0	44	3	120	oil	horizontal	Engineering News 1900
TRENTON FALLS, NY	1901	22.0	12	3	60	air	vertical	Engineering World 1906
Kalamazoo, MI	1901	25.0	46	3	60	oil/ water	horizontal	Engineering Record 1906
Chaudiere Falls, P. Quebec	1901	10.5	10	2	66.6	air	horizontal	Engineering News 1903
Morgans Falls, GA	1904	12.0	16	3	50	water	horizontal	Engineering Record 1904a
Puyallup River, WA	1904	33.0	48	3	60	water	horizontal	Engineering Record 1904b
Catawba River, SC	1904	11.5	18	3	60	oil	horizontal	Electrical World & Engineer 1904
Portland, OR	1905	10.0	15	3	33	none	vertical	Engineering Record 1905
Sewalls Falls, NH	1906	10.8	43	3	60	air	vertical	Engineering Record 1906
Township Falls, GA	1907	13.5	15	3	60	none	horizontal	Engineering Record 1907a
Great Northern Power Co., MN	1907	16.6	14	3	25	oil/ water	vertical	Engineering Record 1907b
Collierville, NY	1908	16.6	18	3	25	water	horizontal	Engineering Record 1908

Initial Operations and Plans for Expansion, c1901-1917

A powerful December 1901 flood in West Canada Creek washed away the Mohawk and Malone Railroad trestle below the dam and the last of the small mills in Trenton Falls Gorge, but left the dam and powerhouse undamaged.⁴⁴ Despite some turbine-related operating problems discussed below, UELP found the plant an immediate success and began plans for market expansion. The company also renovated the Moore Hotel and Kuyahora House shortly after construction ended, hoping to recapture some of the tourist trade, with indifferent results.⁴⁵ In 1902, UELP merged with the Equitable Gas and Electric Company of Utica to become Utica Gas and Electric Company (UGEC), with 145 employees and 8000 gas and electric customers. By 1906, the UGEC service area included Utica, Rome, Ilion, Herkimer, Mohawk, and Little Falls. In 1907, UGEC bought out a number of other firms, including Herkimer County Light and Power Company which serviced Ilion and Mohawk.⁴⁶

The Trenton Falls plant was designed to generate 4000 kw at 2200 v., in four 1000-kw units with a maximum generating capacity of 4800 kw. The Utica electric market was smaller than this capacity when the plant opened, but UGEC soon recognized a need to increase plant capacity as well as market area. In theory, greater available demands by residences, commercial and industrial operations, and street railways over larger areas increased load and diversity factors.* Before 1905, UGEC proposed increasing the Trenton Falls station capacity to 16,000 hp (about 9000 kw), and developing a 6350-hp plant upriver at Prospect plus a 3000-hp plant at Enos on the Black River, nine miles from Prospect. Irregular seasonal flow on West Canada Creek made such plans impractical without additional reservoir storage, however. In low water, Trenton Falls output often fell to 1200 kw, a deficiency recognized when the plant was built and countered by installing two steam stations in Utica with 8000-hp (about 4600-kw) capacity to back up Trenton Falls.⁴⁷

After studying the storage problem, UGEC planned to build the Hinckley reservoir four miles above Trenton Falls dam, and purchased nearly 2000 acres of land for this project c1905. Shortly afterwards, New York State plans for the Barge Canal system were announced to include a reservoir at the same site, leading to state appropriation of the reservoir land and a delay in reservoir construction until 1914. Hinckley Reservoir allowed for full capacity powerhouse operation during peak load hours, and renewed plans for Trenton Falls. The increased industrial demands of World War I, including foreign munitions contracts pre-dating American entry into the war, quickened UGEC interest. With the prospect of an agreement with the state to regulate Hinckley Reservoir discharges, in part to compensate UGEC for appropriated lands, the utility decided early in 1917 to expand the station and began work in April.⁴⁸

*Load factor is the ratio of average load to maximum load; a higher ratio reflects more complete and profitable use of available generating capacity. Diversity factor is the ratio of total customer maximum demands during a given period to maximum demands at transformers at a given moment. Increased customer diversity tended to increase load factor (Hughes 1983: 217-18; Hunter and Bryant 1991: 276-83).

There were few documented modifications at the Trenton Falls plant before 1917. The basic operating regime was greatly simplified by the fact that, for the four relatively small units originally installed, there was usually abundant water at a nearly constant head and with constant tailwater conditions. Plant operators probably soon discovered the primary shortcoming of the Fournayron units, their serious loss of efficiency at part gate, and simply elected to operate them at full gate or turn them off. By so doing, they partially eliminated problems of abrasion and high pressure encountered in using penstock water as the operating cylinder fluid for the Porter-Allen governors. Rather than switch to a more common cylinder fluid of pump-supplied pressurized oil, plant operators by 1917 piped in water from a spring several hundred feet northwest of the powerhouse, and pressurized it with two small I.P. Morris centrifugal pumps driven by penstock-water-powered Pelton wheels mounted in the basement gallery next to the river (see HAER No. NY-155-A).⁴⁹

The two Girard exciter turbines also developed some problems soon after powerhouse completion, because in 1904 they were supplemented by a 115-hp Pelton-wheel-driven generator. At approximately the same time, a type of spool-valve was added to the Girards to control water flow better. It is possible that the internal register-like mechanism was causing trouble. The most obvious potential problems with the Girards was their vulnerability to even small pieces of trash in the penstock water, caused by the small size of the water passages in the nozzle and regulating valve, and aggravated by the difficulty of opening the turbine casing to clear the water passages of trash.⁵⁰

Design and Construction of the Second Powerhouse, 1917-1921

The second Trenton Falls powerhouse, still referred to as the "new" powerhouse by Niagara Mohawk personnel, was designed as a completely independent addition to the old powerhouse with over three times the electrical output. UGEC ran the old powerhouse through the new construction, thereafter operating it as a standby plant usually turned on during high water periods.⁵¹ The initial expansion plan, not fully executed until after the 1919 completion of the new powerhouse, included these major components:

- modification of the dam and headworks to feed a new pipeline, using intakes set in the original dam base and a new high-level intake;

- construction of a 12-foot-diameter pipeline parallel to the original 7-foot-diameter pipeline;

- construction of the new powerhouse, structurally tied to the old one, with three 10,000-h.p., 6400-kw vertical turbine-generator units (units 5-7, continuing the numbering of units 1-4 in the old powerhouse);

- rebuilding and consolidating electrical controls in both powerhouses;

- installing an outdoor transformer and switch yard on the bluff above the powerhouses, with transformers which stepped up generator output to 44,000 volts and fed two transmission lines to Utica and one to Rome (see HAER No. NY-155-A).

Design Considerations

In contrast to the design issues marking the first period of Trenton Falls development, by World War I there was far more standardization in hydroelectric power projects. UGEC engineer Byron S. White supervised several consultants and contractors in a relatively straightforward series of major design decisions for the new powerhouse. The most complex, discussed in HAER No. NY-155-B, involved the dam headworks interface with the new pipeline.

Turbine-Generator Units

Rational turbine choices c1914-17 were relatively clear. UGEC selected American-designed and -built, vertical-shaft, wicket-gate Francis turbines, with spiral inlet cases and top-mounted Westinghouses 6400-kv generators, as the best installation for the power output desired and the available head. For plants of higher head or smaller output, a Pelton could have been an equally good choice, and some might have favored Girarda, but by 1914 the Francis nearly dominated the 50-to-500-foot head range. Instead of the separate turbine-driven exciters used for units 1-4, the new units were installed with integral top-mounted 125-kv exciters above each generator. In most respects these units are as modern as units designed today; this technology advanced rapidly in the short time between the building of the two powerhouses. The Lombard oil-pressure governors on turbines 5-7 closely resemble modern units, even though they were partially upgraded later with Woodward flyball heads and oil pumps. Relative to later practice, the only somewhat eccentric aspect of the units 5-7 was the waterpowered hydraulic cylinders which opened and closed the original gate valves. This was a simple way to operate the valves, but may not have worked well with mid-20th-century electrical and electronic controls; motorized butterfly valves later replaced the hydraulic cylinders.

The designer(s) of the turbines 5-7 are unknown. This is not unusual, since design criteria for Francis turbines of this head and output were well known by 1917. Niagara Station No. 2, built at the turn of the century, laid the groundwork, and essentially every other site of over 1000 kilowatts output at heads over 100 feet followed suit. Except for installations on the edge of technology, the day of the turbine designer as engineering celebrity was over.

UGEC had turbines 5 and 6 installed in 1918, when the new powerhouse was under construction.⁵² Platt Iron Works of Dayton, Ohio, builders of these two turbines units 5 and 6, provide an interesting contrast with the I.P. Morris Co. Platt evolved from a group of skilled turbine designer-builders in the Dayton-Springfield, Ohio area, including the very prolific James Leffel & Company, the Dayton Globe Iron Works, and Stout, Mills and Temple. Platt's immediate predecessors were the Stillwell-Bierce Manufacturing Company and the Smith-Vaile Company, both makers of the Victor brand turbine which "...resembles the McCormick pattern" of mixed flow Francis runner.⁵³ These firms merged to form Platt c1906. Both Victor-makers were typical of small American turbine firms of the late 19th century, building the so-called "stock-pattern" or "American" mixed-flow runner, Francis-variant turbines with most design work done on a cut-and-try basis utilizing the Helyoke Test Flume to sort out the improvements from the failures.

Stillwell-Bierce was notable for submitting a bid on the turbines for Niagara Station No. 1,³ and c1903 offered a high-pressure turbine for heads of about 70-700 feet to fill the gap between the mixed flow reaction turbines and the Pelton.³⁴ This work appears to represent a break with the earlier non-scientific practices of the company, which as reorganized was able to win the design and construction contracts for the 10,000-h.p. units of the second Trenton Falls powerhouse. Platt's largest other identified units after Trenton Falls are 10,000-h.p. vertical Francis turbines for the School St. plant in Cohoes, New York, built 1915-22.³⁵ Platt and its predecessors were also perhaps the primary American makers of the Girard, building units as large as 1000 h.p.

Unit 7 was installed in 1921, after completion of the new powerhouse and a new high-level intake at the dam. Unlike the simple elbow draft tubes of units 5 and 6, number 7 has a more complex Moody spreading and/or concentric draft tube, developed through extensive testing to increase head and reduce cavitation. The draft tube and an improved runner were credited with giving Unit 7 a capacity of 8000 kw rather than 6000.³⁶ The different draft tube may reflect some type of early cavitation problems in units 5 and 6.

The Hamilton, Ohio-based Hooven, Owens, Rentschler Company, builders of turbine 7, originated in 1845. The firm manufactured a wide range of industrial machinery and steam engines, and specialized in large Corliss steam engines in the late 19th century before entering the turbine field to retain electrical generating equipment business. In 1928, a merger with the Miles Tool Works created the General Machinery Corporation.³⁷

Other Major Components

The new powerhouse, described in HAER No. NY-155-A, is a steel-framed, reinforced concrete structure with a flat, parapeted roof. With remote control switchboards located on a generator-floor mezzanine balcony and a low upper story, it was entirely typical of powerhouses built after c1910-15 in New York State, as were most 1917-21 additions to the complex.³⁸

Construction

The largely wartime construction program was hampered by severe 1917-18 winter conditions and much labor turnover. The U.S. Structural Company, acting as general contractor, hired over 2000 people to fill about 200 jobs. As with the old powerhouse and dam construction in 1899-1901, both hotels -- still maintained by UGEC -- were filled, and a shantytown area at the junction of the railroad crossing of the gorge and narrow-gauge built to serve the construction project. Military guards appeared, reflecting the wartime sensitivity to sabotage of power installations. There were particular problems with a pipeline connection. Despite these difficulties, and the need to excavate thousands more cubic yards of rock for the powerhouse, units 5 and 6 were started in September 1918 and March 1919, respectively. Soon thereafter, UGEC concluded its agreement with the state on regulation of Hinchliff Reservoir, built primarily to serve a Barge Canal feeder which tapped West Canada Creek immediately below the powerhouses.³⁹

The delay in installing unit 7 until 1921 reflects water intake problems not fully addressed until the early 1930s. As detailed in HAER No. NY-155-B, the 1917 plan included feeding the new 12-foot-diameter pipeline with two 5-foot-diameter intakes built into the dam c1899-1900, and with a High Level Intake immediately northwest of the dam. As expected, the pipeline was connected to six original dam intakes via a complex manifold (see Part II below), but only the two initially intended for the pipeline were provided with trash racks and opened. There was apparently insufficient water delivered to run three new units until the 1921 construction of a redesigned High Level Intake, with two concrete tunnels whose bottom elevations were 20 feet above the intakes in the dam. The tunnels fed a 10-foot-diameter concrete tunnel which took water from the High Level Intake around the dam to the 12-foot-diameter pipeline. Flashboards were raised on the auxiliary spillway, and first installed on the main dam spillway, at this time to increase retention of spring high water.⁶⁰

Operations, Maintenance, Rebuilding, and Corporate Consolidation, 1921-1993

Within about a year of installing Unit 7, UGEC raised the flashboards at the main and auxiliary spillways, and replaced the turbine runners in units 5 and 6 with "improved" runners similar to the one in Unit 7. These changes gave each of the new powerhouse units a capacity of about 8000 kw, and the entire station a 28,000-kw rated capacity.⁶¹ In practice, units 1-4 operated only about 20% of the time, on peak load or during high water, and leakages discussed below soon diminished new powerhouse output to about 26,000 kw.⁶² Even with these limitations, Trenton Falls Station was among the largest hydroelectric installations in New York State in the mid-1920s, ranking eighth or ninth among some ninety-six then running, and was the principal source of UGEC power.⁶³ The utility made this station something of a showplace at this time, allowing public recreational use of the site and powerhouse visits. The hotels were now closed to the public, however, and became company facilities or were demolished. In 1923, UGEC dismantled much of the Moora Hotel and remodeled the dining room and porch as an employee Club House, used for picnics. The Club House stood until 1945, when it was completely removed following the collapse of the roof under snow load.⁶⁴

The nationwide growth of public utility holding companies, beginning c1905, increased dramatically during the 1920s. In 1925, the General Electric Company and associated investors organized the Mohawk Hudson Power Corporation to secure ownership of utilities in the Mohawk and upper Hudson valleys. Mohawk Hudson quickly acquired all the common stock of UGEC, which remained under separate management. Mohawk Hudson utilities became part of a larger electric network interconnected across the state, and benefitted from some consolidated management practices. An even larger holding company, Niagara Hudson Power Corporation, emerged in 1929 as the world's largest electric utility system, and acquired Mohawk Hudson, along with two other large New York utility groups. One early Niagara Hudson management goal, consolidation with Mohawk Hudson, finally occurred in 1937 as part of a larger consolidation of companies within Niagara Hudson, then renamed Central New York Power Corporation. UGEC ceased to exist at this time. In 1950, additional consolidation of original Niagara Hudson corporations created Niagara Mohawk Power Corporation.⁶⁵

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There were no significant changes made to the Trenton Falls Station under Mohawk Hudson, but Depression impacts on Niagara Hudson earnings began a long series of alterations designed to improve plant efficiency, upgrade site facilities and equipment, and reduce operating costs. These alterations, continuing today, reflect the larger engineering staffs and capital common to utility groups after 1920, resources themselves dependant on continual attention to system efficiencies.

In 1931, inspections at Trenton Falls revealed leakage totalling 22.4 cfs from untreated wooden portions of the 7-foot-diameter pipeline -- most of which was buried when first built -- and from the 5-foot-diameter gate valves at the Fournayron turbines in the old powerhouse. These leaks lost about 2% of the plant's annual output of 130 million kilowatt-hours. There were also losses of head through the two intakes feeding the 12-foot-diameter pipeline, and friction losses in that pipeline, which analysis by Niagara Hudson engineers indicated could be overcome by opening the four remaining unused intakes at the dam. After considering closing the old powerhouse or running both powerhouses from the larger pipeline, UOEC rebuilt the old pipeline and completed other improvements in 1931-32 which increased total station capacity to some 27,500 kw (a 5% increase) and upgraded safety and hydraulic control features.

From the dam to the powerhouses, this program included:

- installing new trash racks at intake pipes and adding the four remaining intakes to the 12-foot-diameter pipeline;

- replacing belt-driven intake gate valve operators, on single shafts in the gatehouses built c1900 and c1918, with individually-operated, motorized controls operable from the powerhouses and the gatehouses;

- replacing the older wood pipeline in steel, on above-ground steel and concrete saddles, with new gate and air valves;

- installing a butterfly-valve-controlled connection from the smaller to the larger pipeline, allowing operation of the new powerhouse from both lines and a savings in head of 6.7 feet when the old powerhouse was not operated;

- repair and upgrading of turbines 1-4, with electric-motor-driven gear-reduction units replacing original Pelton-wheel gate valve operators, welding and restoration of pitted bronze runner surfaces, and replacement of the pressurized-water governors with variable-speed DC motors linked to Westinghouse speed-sensing relays atop each generator;

- installing an automatic signalling device at the upper end of the 12-foot-diameter pipeline, to alerted powerhouse operators of breaks in the pipe or drops in water pressure, and automatically close turbine gate valves and open generator oil circuit breakers at danger levels.⁶⁶

The gain in station capacities was obtained at a cost/kw about two-thirds that of the station in c1930, and about half that of increment steam energy to achieve the same increase.⁶⁷

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For over fifty years, the 1931-32 program of waterpower improvements needed relatively little enhancement. In 1933-34, the Wertz Company (Cleveland, Ohio) conducted minor repairs and waterproofing of the dam, auxiliary spillway, and High Level Intake.⁶⁸ At the same time, gate valve operators on units 5-7 were replaced by motor-driven butterfly valve operated through Limitorque drives. In 1941, the Lombard governors on units 5-7 were modified by replacing the original Lombard flyball head and oil pumps with more modern Woodward units, while retaining the Lombard operating cylinders. A floodgate was installed in the main dam spillway in 1951-52. Aside from runner replacements, the last significant changes in turbine hardware occurred in 1965 when the manually-operated brakes, operating against a pulley above each runner in units 5-7, were modernized by the addition of an air compressor and air cylinders to allow remote operation. The pipeline pressure and signalling system was also upgraded in 1965 (see HAER No. NY-155-A).⁶⁹

There were far fewer changes after 1921 made in electrical control, output, and transmission facilities, which were never subject to the earlier design or construction limitations seen in some of the hydraulic features. In 1942, Central New York Power built a new substation north of the original transformer yard, and generated directly from units 1-4 to the substation. This project, including rerouting of the old powerhouse transmission lines, led to removal of indoor air-blast transformers, demolition of an original lightning arrester house, and construction of a steel tower immediately west of the station to support the new lines. There were several episodes of oil circuit breaker replacement in both transformer yards, which were rebuilt c1959. Beginning in 1965, Niagara Mohawk converted the station to automatic remote control, using technology first available in the 1920s, and later upgraded these controls (see HAER No. NY-155-A).

During World War II, Central New York Power intensified use of its hydroelectric facilities, in some cases reconditioning and moving underutilized, older equipment to other sites.⁷⁰ There were virtually no changes made at Trenton Falls Station in this period, but a general War Department ban on public access to power stations eliminated authorized recreational use of most of Trenton Falls Gorge. Central New York Power and Niagara Mohawk have to date continued this restriction -- difficult to enforce in the face of the gorge's fierce attractiveness.⁷¹ Since World War II, private utilities have built few large hydroelectric stations in New York State, and some older sites have been retired. Niagara Mohawk has retired about twenty small stations since 1950, but intensified use of its waterpower resources in the 1950s by adding seven stations with total capacities of about 150,000 kw. These included the 18,200-kw Prospect Station, opened in 1959 below Hinckley Reservoir less than a mile north of Trenton Falls Station.⁷² After 1970, hydroelectric energy received renewed attention in the face of declining confidence in nuclear power, and increasing costs of acquisition and pollution control associated with fossil fuels. Maintaining or upgrading older stations like Trenton Falls remains a major issue for Niagara Mohawk, which owns over seventy hydroelectric plants -- one of the largest such networks in the world. Trenton Falls Station is still one of the oldest and largest in New York State, ranking about thirteenth in rated capacity among over a hundred operating stations, even after construction of several extremely large plants by public agencies.⁷³

The value and capacity of Trenton Falls depends primarily on its aging and relatively large-scale system of hydraulic controls, which periodically require extensive attention. By 1980, the 12-foot-diameter wooden pipeline was deteriorating and the upper end of the smaller pipeline collapsed after a vent froze. As part of a planned major rebuilding of the station, including replacement of the Fournayron units, Niagara Mohawk between 1983 and 1985 removed virtually all of the two pipelines and their associated standpipes and vents, replacing them with a single 14-foot-diameter steel pipe fed by a concrete-lined tunnel running from the complete-rebuilt High Level Intake.

The new pipeline program included other hydraulic improvements, with new flashboards at both spillways and refurbishing of intake gate guides and trashracks. The only significant remnants of the 1899-1931 pipelines, aside from empty saddles, were below the 1931 cross-over between the two earlier pipelines, above the powerhouses. On the remaining 12-foot-diameter steel pipeline, repair of a wood-shingled steel surge tank in 1983 resulted in a fire requiring the complete replacement of the tank.⁷⁴

The planned replacement of the Fournayron units was eventually canceled, but not before the station was relicensed with the Federal Energy Regulatory Commission for operation with only units 5-7. Niagara Mohawk ceased running units 1-4 in May 1988, but remains committed to long-term use of units 5-7. Current maintenance involves replacement of runners and upper draft tubes, to address cavitation noted c1990, and completion of a 1992-93 program upgrading dam surfaces, drainage systems, flashboards, and stairways (see HAER No. NY-155-B).⁷⁵

Significance of Trenton Falls Station

Hydroelectric Development

For many years, Trenton Falls Station has been regarded as significant because when first built it had the [then] highest-head reaction wheels in the United States, and the first such turbines "...designed according to modern scientific methods by an American designer and ... constructed by an American builder."⁷⁶ If one ignores the earlier installation of high-head Pelton wheels in the American West, the first claim is apparently true. Developed at a head even higher than Niagara in what was at the time a relatively remote area, Trenton Falls demonstrated that a relatively small company could complete a project of this scale, and provided added assurance to prospective investors in high head plants. The station's general impact on new development is hard to measure, however. Regional geology constrains most Eastern American sites to be low head, and the approximately 12-mile transmission distance between the old powerhouse and Utica was hardly path-breaking relative to trans-Mississippian developments (Table 1).

The claims made for early American turbine design are overstated. It is true that Trenton Falls, like the first Niagara station, had reaction turbines designed and built specifically for these high-head applications, in contrast to the use of standard or stock American-made turbines, which were not at the time usually available for heads over about 70 feet in reaction models. Although William Monroe White's adaptation of the Girard design may have been original, the clear re-use of Swiss-made Fournayron patterns for the main Trenton Falls wheels belies his reputation as a theoretical designer.

If design originality is measured against engineering judgement, these turbines were a technological dead end rather than a significant achievement. Trenton Falls Station was first designed and built during the period of development stimulated by the Niagara Falls development, and before the earlier station's design shortcomings became widely known in the engineering fraternity. Had Utica Electric Light and Power waited another few years to build at Trenton Falls, the turbines chosen would likely have been quite different from the package presented by Brackenridge in 1899 and built the next year.

In contrast to the turbines, the 1899-1901 electrical systems and equipment, along with the dam and powerhouse designs, represent durable although not necessarily highly unusual choices. Clearly a transitional installation, the original Trenton Falls Station was among the first high-voltage systems in the eastern United States (see Table 1). This station also combined the then-novel Eastern American use of high-head generation with older technologies, notably in the varied and extensive use of water power for many plant operations. Station designers were perhaps not fully trustful of their new technology, relying on the more proven hydromechanical drives for turbine gate valves, water pumps, station service generator, and governor operating cylinders. Soon after this station was built, all such auxiliaries would have been powered by electric motors.

Surviving Site Resources

The Trenton Falls Station today is most significant as a fascinating study in contrasts between two very different generations of hydroelectrical engineering, physically juxtaposed in one powerhouse structure. Dramatic differences in the scale and style of the two powerhouses immediately highlight the major episodes of equipment design, construction, and installation. Despite the removal of the long pipelines linking the dam to the powerhouses, survival of the dam largely unaltered preserves the scale and drama of the early-20th-century hydroelectric project (see HAER Nos. NY-155-A and NY-155-B).

The old powerhouse's highly-engineered, European-styled turbines promised much, but for their cost and complexity, delivered relatively little. All parties involved in the design were at or near the apex of their careers, which along with UELP consciousness of the project's importance explains why no details seem to have been spared to make the plant truly first class. It is a tribute to the over-engineering of units 1-4 that they are all fully operable with no major repairs after nearly ninety years of use -- admittedly, light use after 1917. By contrast, units 5-7 are simple, functional, generic turbines, like hundreds of others installed at similar sites world-wide in the past ninety years. One of the most startling differences is the small size

increment between the two sets of turbines. The Francis units generate about six times the power of the Fourneyrons, with runners only four inches greater in diameter (57 vs. 53 inches). Where units 1-4 have separate exciters driven by relatively large, complicated Girard Turbines, the Francis units have exciters built onto the tops of their generators. If built to the same power-to-size ratios as units 1-4, units 5-7 would be four times their actual size.

Units 1-4 and their Girard exciters are the last surviving utility plant examples of two turbine types that never became popular due to high manufacturing costs and design limitations. Units 5-7 are early examples of a revolution in turbine design, re-establishing American dominance in the field that would last until the 1980s. The Fourneyron is only a footnote of historical interest in most books on turbine evolution, the Girard even more obscure, but here in one small building they remain in one of their finest installations in North America. Seldom do quirks of technology survive in such style.

The survival of some original Trenton Falls electrical equipment reflects the quality of design decisions in a pivotal period, of extant Niagara Mohawk 60-cps stations retaining original equipment, few if any are older. Continual change at Trenton Falls has not left it an intact specimen of 1900 period, however. The new powerhouse project included revised control systems for the old station. Original air blast transformers, low and high tension switches and transmission towers were modified or eliminated over the years, until today the generators and exciters are the only major surviving pieces of original electrical gear (see HAER No. NY-155-A). The survival of the original generators and exciters without the control or transmission equipment is not unusual: rotating machinery of the period often achieved efficiencies of 98% -- levels hard to equal today. The original generators are also beautiful examples of contemporary heavy electrical engineering, with the flared bases and rounded tops of the stator shells soon to give way to more hard-edged utilitarian designs. The machines were massively overbuilt, partially explaining their long life-span. By contrast, the original switchgear and transformers were both fragile and dangerous by modern standards. High-tension circuit-breakers near the control boards exposed operators to electrocution and fire hazards. Numerous auxiliaries were controlled by hand-operated carbon circuit breakers which could flash and disintegrate under severe overloads. Indoor transformers required high tension leads to be brought into the building with attendant risks.

The new powerhouse represents a period of increasing sophistication in electrical control. Switchboards were equipped with low-voltage remote control of distant high voltage switches. Protective devices monitored all functions of the generators, allowing operators to run entire stations without leaving the board area. This generation of technology allowed for largely unmodernized operations to the present time, one reason why the new powerhouse -- while in almost original condition -- is by itself neither especially significant nor unique. Coupled with the old powerhouse, however, the new one gives Trenton Falls Station a generation-spanning quality rarely seen elsewhere.

Part II - Descriptive Information

Summary of Site Arrangement and Existing Conditions

Trenton Falls Station is located primarily in the Town of Trenton, Oneida County, on the west bank of West Canada Creek beginning about 1.3 miles below Hinckley Reservoir. The station dam extends across the creek to meet the auxiliary spillway, in the Town of Russia, Herkimer County. When Utica Electric Light and Power began station development in 1899, it acquired about 106 acres on both sides of the creek (including water rights), on about 40 of which all major station components have since been built. With other land abutting the project purchased into the 1930s, Niagara Mohawk today owns over 129 acres in the immediate station vicinity.⁷⁷

Station development had several effects on Trenton Falls Gorge. All traces of the 19th-century resort development were removed by 1945, except for a Moore family cemetery just outside Niagara Mohawk property, west of the substation on the bluff above the powerhouses. Large amounts of rock were removed from the west side of the gorge at the powerhouses site, and at the dam site, especially the auxiliary spillway. Except during spring run-off, when water roars down the gorge, the dam and diversion of water for station use leaves the rock-bottomed canyon dry. Construction of pipelines and roads between the powerhouses and the dam has removed the forest cover which otherwise spills over the sides of the gorge.

The station is a relatively complex site, with four major groups of components spanning a distance of about .75 mile along the creek along the south-flowing creek ;

- the dam and headworks, including the auxiliary spillway, intake and waste pipe controls on a headworks structure with c1900 and c1918 gate houses, connections between intakes and pipelines, and the 1921 High Level Intake modified for the 1984 14-foot-diameter pipeline;

- pipelines built or modified c1900-01, 1917-23, 1931-32, and 1984-85, with associated standpipes, valves, vents, and surge tanks;

- the powerhouses completed in 1901 and 1919, with associated penstocks, a lightning arrester house, and substations built or modified beginning in 1942 including a hoist house;

- storage buildings or barns, and employee residences.

The average pond elevation behind the dam is about 39.5 feet above the intakes which fed the 12-foot-diameter pipeline, which dropped some 112 feet over about 3600 feet to a manifold attached to penstocks feeding units 5-7. These penstocks dropped over the edge of the gorge 106 feet to the turbines, set 8 feet above average tailwater in the creek bed, for a total average head of about 265.5 feet.⁷⁸ The 7-foot-diameter pipeline ran nearly 3900 feet and had different elevation points, but the head was identical.

The pipelines pre-dating 1984 are gone except for saddles and retaining walls, and the lower ends joining the turbine penstocks. The newest pipeline creates a radically different link between the dam site and powerhouse area, and at present has no historic significance except as an artifact of continuing station use. Some of the earlier auxiliary structures survive, but many have been demolished or rebuilt, and none appear individually significant. By contrast, the powerhouse and substation area, and the dam and headworks complex, retain much original fabric and give Trenton Falls Station virtually all of its historic importance. The powerhouse and substation are described in NY-155-A; NY-155-B covers the dam and headworks. The other, largely vanished components are documented below.

Pipelines Prior to 1984

Open races, the original conveyors of waterpower, are not efficient in high-head situations with long distances and irregular terrain. To maintain consistent water pressure, closed circular pipes soon became common at hydroelectric installations in such situations.²⁷ With continuous pressure conduits, it is somewhat arbitrary to distinguish pipelines from penstocks, which deliver water directly to turbines. At Trenton Falls, a fairly typical distinction appears in original drawings or descriptions, with the penstocks beginning at the edge of the gorge, just below the lowest standpipe or surge tank. The pipelines were typical of large hydroelectric projects c1900-1930, reflecting a preference to maximize use of wood staves, which are readily transportable to remote areas and have low coefficients of friction. Often cheaper than welded or riveted steel, wood pipelines require no expansion joints and are less prone to freezing. Iron or steel hoops, run through cast-iron dogs and bent over, retain the wood sections.²⁸ Greater pressure requires more hoops per running foot, however, and above about 125-150 feet of head the hoops are so close together that steel becomes more economical.²⁹

High-head pipelines operate under considerable pressure, and are subject to two principal types of catastrophic failure. Sudden closure of turbine gate valves, while pipeline intakes remain open, can lead to severe water hammer damage with uncontrollable pressure exerted from inside the pipeline. The opposite problem, of sudden loss of pressure in the pipeline, can occur if turbine gates remain open when intakes close, storage pond levels suddenly drop, or the water column separates at an abrupt change in pipeline gradient. These conditions can create vacuums leading to pipeline collapse.³⁰ Standpipes or surge tanks, located at or near pipeline bottom elevations, prevent water hammer damage, and required vertical pipes as large as the pipelines reaching elevations higher than any possible pond level. To allow air to enter the pipeline immediately upon any water column interruption, hydroelectric engineers installed smaller standpipes of less diameter than the pipeline, or float-activated air valves, at upper pipeline elevations and at any sharp gradient changes. Prevention of freezing was essential for all vents, standpipes, or related structures. Trenton Falls Station included such typical pipeline accessory features, fully developed by the time of new powerhouse construction, including a differential surge tank on the 12-foot-diameter pipeline.³¹

7-Foot-Diameter Pipeline Serving Old Powerhouse

Initial Construction, 1899-1901

At the dam headworks, a cast-iron Y-shaped connector entered the pipeline from two 5-foot-diameter intake pipes, beginning immediately south of the gate valves in the valve or gate house (see HAER No. NY-155-B). For about 2900 feet, the pipeline consisted of 2 3/8-inch-thick untreated yellow pine staves, set longitudinally with twenty staves forming the pipeline circumference and banded with iron hoops closed with iron dogs. Set on pine sills, most of the wooden section was buried. The lower 987 feet of pipeline was lapped, riveted steel plate, of between 3/8 and 5/8 inch thickness, mill-coated inside and out with asphalt pitch. Angle iron stiffened the 3/8-inch-thick plate. The steel pipeline also ran underground, except for the southernmost 100 feet which joined a single penstock to the first powerhouse (see HAER No. NY-155-A). A 7-foot-diameter, 175-foot-high standpipe, 20 feet high than the dam crest, rose from the pipeline about 150 feet from the penstock. Built of 5/8-inch-thick riveted steel plate, the standpipe was sheathed with an 11-foot-diameter, wood-shingle frost casing 185 feet high, rising from a 12-foot-high, 23-foot-diameter concrete foundation. The standpipe was steam heated in winter, had 96 60-watt lights on the outside of the frost casing, and was equipped with a beacon light. Three smaller air vents also served the pipeline, the largest of which was a 2-foot-diameter cast-iron pipe immediately below the gatehouse. Running into the pipeline from the slope just west of the headworks, this vent was 43 feet high, and sheathed with a 4.75-by-4.2-foot wood casing. 84

1931 Rebuilding

Farrar and Trafts (Buffalo) replaced the wood pipeline section with an 2757-foot aboveground line of 3/8-inch-thick steel plate, with electric-welded longitudinal and riveted girth joints, and eleven expansion joints. The new pipeline rested on concrete and steel saddles, and crossed a small ravine on a plate-girder bridge about 1300 feet south of the dam headworks. The original steel section, standpipe, and uppermost air vent were retained. Two 8-inch air valves at the pipeline's highest elevation, about 1200 feet north of the 7-foot-diameter standpipe, housed in a 6-foot-high, 7.75-by-8.3-foot frame structure. The 1931 project also included installation of a 7-foot-diameter, 5/8-inch-thick steel plate cross-over pipe between the two pipelines. 85

Modifications and Removal

Niagara Mohawk removed the standpipe in 1959, replacing it with an access port. A Limitorque gate valve, installed within a concrete bunker just below the cross-over pipe, may have been added at this time. After construction of the 14-foot-diameter pipeline in 1984, the 7-foot-diameter pipeline was removed above the cross-over between the two older pipelines, leaving the southernmost 350 feet of the original steel pipeline, empty saddles, and a short section of pipe at the dam headworks. 86

12-Foot-Diameter Pipeline Serving New Powerhouse

Initial Construction, 1917-1923

The pipeline serving the new powerhouse tapped a complex array of six 5-foot-diameter intakes installed in the dam when the old powerhouse was built. Of eight intakes, the western two fed the original pipeline. The next two to the east, plus the easternmost four installed nine feet below the western intakes, required an unusual connection to the new pipeline, including continuing use of the two easternmost intakes as waste pipes. Immediately south of a new gate house controlling the six intakes, and set within a greatly enlarged concrete headworks structure, a steel reducing manifold centered at the elevation of the two higher (western) intakes linked the intakes to the 12-foot-diameter pipeline. Cast-iron bands and Y-shaped connectors linked the four lower intakes to the manifold, and also allowed the two easternmost pipes to continue through the headworks.⁸⁷

From the manifold, the northern 2680 feet of pipeline consisted of Douglas fir staves with iron bands and dogs, supported on 423 concrete saddles averaging 7 feet apart. Cement grout joined the wood pipeline to the saddles, some of which rested on concrete piers 10-to-20 feet high at several points as required by terrain. One plate-girder-framed, 75-foot-long, concrete-slab bridge supported the wood pipeline over the same small gully later traversed by the rebuilt 7-foot-diameter pipe. The southern 710 feet of pipeline was 5/8-inch-thick riveted steel, constructed in 8-foot sections on 36 concrete saddles, ending in another steel reducing manifold on 4 concrete saddles. The southernmost manifold reduced the pipeline to 9 feet in diameter and joined it to three separate 7-foot-diameter penstocks feeding units 5-7. Concrete retaining walls ran along the slope edge above the penstocks (see HAER No. NY-155-A).⁸⁸

The 12-foot-diameter pipeline was built between the earlier pipeline and West Canada Creek, an extremely narrow construction area. Proximity of the two pipelines required nearly 700 feet of thin concrete wall between them, installed discontinuously over a distance of some 1500 feet below the headworks, to maintain the earthen cover on the old pipe and protect the buried pipe against blasting. For about 800 feet below the dam, the new pipeline ran along the edge of the creek, above a 12-to-15-foot-high concrete retaining wall protected by an 82-foot-long flood diversion wall extending into the creek south of the railroad trestle.⁸⁹

A steam-heated, 9/16-inch-thick, steel-plate, differential surge tank rose 187 feet above the pipeline about 150 north of the penstock manifold. Above a 12-foot-diameter, 110-foot high riser, the 40-foot-diameter, 69-foot-high tank had a 619,000-gallon capacity, and rested on 140-foot-long steel girder legs set on six 22-foot-high concrete bases. Shingled wood casings surrounded the tank and riser, 52 and 18 feet in diameter, respectively. Construction of the 12-foot-diameter pipeline included a heated, 55-foot-high, 6-foot-diameter air vent at the lower end of the dam headworks, also wood sheathed.⁹⁰

Addition of the High Level Intake in 1921 included linkage of a 10-foot-diameter steel pipe to the 12-foot-diameter pipeline, about 35 feet south of the 6-foot-diameter vent at the headworks (figures 9 and 11). In 1923, after all three units in the new powerhouse were operating, UGEC added a second, 4-foot-diameter, 77-foot-high standpipe about 1150 feet north of the surge tank, at the highest elevation on the pipeline. Heated and shingled like the other pipeline vents, this standpipe included a gable-roofed, 18-by-30-foot frame structure at ground level, with an I-beam-supported concrete floor, a door, and a single window. ⁹¹

Modifications and Removal

There were few intentional modifications to the 12-foot-diameter pipeline prior to its 1985 removal. During the 1931-32 program of hydraulic repairs, the automatic signalling device, capable of automatically closing new-powerhouse turbine gate valves and opening generator oil circuit breakers at danger levels, was installed at the 4-foot-diameter standpipe (perhaps associated with construction of the house-like structure noted above).⁹² The signalling device was upgraded in 1965. In 1931, a 14.8-by-9.5-foot frame air-valve house was installed on the pipeline at a location not clear from materials reviewed for this documentation, and the cross-over pipe and butterfly valve noted above connected the two pipelines.⁹³ Following the 1983 fire at the surge tank, a new structure of similar size was completed in 1984 using the original base supports, but without the wood sheathing -- by then believed unnecessary for winter protection.⁹⁴

The 1985 removal of the 12-foot-pipeline left conditions similar to those noted for the 7-foot-pipeline: the southmost 180 feet of the original steel pipeline and penstock manifold, empty saddles, and a short section of pipe at the dam headworks. ⁹⁵

Auxiliary Structures

In addition to 19th-century buildings associated with the Moore Hotel, all probably demolished by 1943, the utilities owning Trenton Falls Station built the following structures:

1. A two-story, cross-gabled frame Dam Carekeeper House, about 57 by 28 feet in plan, built c1900 and used as an employee residence until demolished in 1941.⁹⁴
2. A 1909 frame two-story barn and one-story garage, with concrete foundation, on the road south of the powerhouse; not extant.⁹⁷
3. A 1916 two-story, concrete-and-frame superintendent's house, about 44 by 18 feet, on the same road; intact.⁹⁸
4. A 1916 two-story barn, about 35 by 36 feet; not extant.⁹⁹
5. A 1920 concrete oil house on the bluff above the new powerhouse, about 13 by 10 feet with a peaked roof, possibly installed c1917 as a compressor house for new powerhouse construction; demolished 1974.¹⁰⁰
6. A small 1920 shed at the superintendent's house; demolished.
7. A 1920 frame storeroom southward of the dam, about 50 by 20 feet with a moderate foundation; replaced by a metal building in 1981.¹⁰¹
8. A 1931 steel-framed, metal-sided house house on the bluff above the new powerhouse; not extant.¹⁰²

William R. ...

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Notes to Parts I and II

1. Dunlap 1896: 402; Thompson 1977: 26; White 1918: 1028; White 1927: 3-5.
2. Pratt and Pratt 1978: 8-14.
3. Thompson 1977: 155-64.
4. Thomas 1951: 9, 43-5, 61, 65, 88-94; Pratt and Pratt 1978: 15-16.
5. Thomas 1951: 88-94, 133-35.
6. Hunter and Bryant 1991: 254.
7. Benack 1974: 37.
8. New Century Club 1900: 33-41; Cokinham 1912: 444-54; Thompson 1977: 179-80.
9. Benack 1974: 211-24.
10. Thomas 1951: 137-8.
11. Dunlap 1896; Benack 1974: 24-5.
12. Thomas 1951: 137-40; Benack 1974: 211-24.
13. E.g., Niagara Mohawk Power Corporation, 2-T7-H2: Brackenridge 1899a-c [plans].
14. Thomas 1951: 141.
15. Thomas 1951: 144; White 1927: 8-10; cf. Hay 1991: Appendix C.
16. Hunter and Bryant 1991: 255.
17. Hay 1991: 19.
18. Ibid: 263-6.
19. Martin and Coles 1922: 133.
20. Hunter 1979: 328-333.
21. Emerson 1894: 200.
22. Hunter 1979: 388-96; Hunter and Bryant 1991: 264-5.
23. Adams 1927.
24. White 1927: 8-13.

25. Niagara Mohawk Power Corporation, 2-T7-H21: I. P. Morris Co. 1906a [plans].
26. DeWald 1904.
27. Buvinger 1906.
28. Nagler 1923.
29. Nagler 1923; Barrows 1943: 221.
30. Niagara Mohawk Power Corporation, 2-T7-H21: Felton Water Wheel Company 1899 [plans].
31. Adams 1927: I, 144.
32. Adams 1927: I, 164; Passer 1953: 175.
33. Adams 1927: II, 236.
34. *Electrical World* 1906: 1030.
35. *American Electrician* 1897: 332, 1898a: 55.
36. Passer 1953: 365.
37. Passer 1953: 315.
38. *Engineering Record* 1905: 176.
39. Passer 1953: 315.
40. Thomas 1951: 144-8.
41. White 1927: 8-13.
42. Rushmore and Lof 1917: 170; Hay 1991: 58-60.
43. Benack 1974: 211-24.
44. Thomas 1951: 9, 149-51.
45. Thomas 1951: 156; Ellis 1987.
46. *Electrical World* 1906: 1031; Benack 1974: 211-24.
47. *Electrical World* 1906: 1031; White 1927: 8-13.
48. White 1927: 8-13.
49. Correspondence files, 2-T7-H21, June 20, 1931 and October 12, 1932. Niagara Mohawk Power Corporation.

50. Niagara Mohawk Power Corporation n.d.
51. White 1918: 1028.
52. White 1927: 8-13.
53. Horton 1906: 124, note b.
54. Horton 1906: 125, note a; Beardsley 1907: 334.
55. Niagara Hudson Power Corporation 1931: 209; Hay 1991: Appendix B.
56. White 1927: 8-13.
57. General Machinery Corporation 1945; Hunter and Bryant 1991: 344.
58. Rushmore and Lof 1917: 176-9, 192; Hay 1991: 58-60.
59. White 1927: 8-13; Thomas 1951: 152-4.
60. White 1927: 13; Thomas 1951: 152; Collegly 1931; Carr 1934.
61. White 1927: 13.
62. Carr 1934.
63. Hay 1991: Appendix B; White 1927: 13. Other UGEC hydroelectric stations at this time included Little Falls on the Mohawk River and Dolgeville on East Canada Creek, along with the Washington Street steam plant in Utica. The Harbor Point station replaced Washington Street in 1926 (Benack 1974: 211-24).
64. White 1927: 13; Thomas 1951: 171-3.
65. Benack 1974: 222-4, 481-7, 521-35, 625.
66. Collegly 1931; Carr 1934; Niagara Mohawk Power Corporation n.d., and correspondence files 2-T7-H4, 2-T7-H11, and 2-T7-H20.
67. Carr 1934.
68. Correspondence file 2-T7-H2, Niagara Mohawk Power Corporation.
69. Niagara Mohawk Power Corporation n.d.
70. Hay 1991: 90.
71. Ellis 1987.
72. Hay 1991: Appendix C.
73. Cf. Carr 1934 and Thompson 1977: 288-89, Table 31.

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74. Niagara Mohawk Power Corporation files, untitled; interviews with Niagara Mohawk engineering personnel (see Part III).
75. Personal communications, Robert Shantis and Robert Dolan.
76. White 1927: 8; also see Barrows 1943: 209.
77. Niagara Mohawk Power Corporation n.d.
78. Niagara Hudson Power Corporation 1931, and 2-T7-H3: Utica Gas & Electric Company n.d. [plans].
79. Mead 1915: 592.
80. Barrows 1907: 200-206; Hay 1991: 36-7.
81. Rushmore and Lof 1917: 131; White 1918: 1029; Barrows 1943: 399.
82. Rushmore and Lof 1917: 128; Barrows 1943: 566.
83. Rushmore and Lof 1917: 141-4; White 1927: 11-12; Barrows 1943: 563; Hay 1991: 37-8.
84. Electrical World 1906; White 1927: 10; Niagara Mohawk Power Corporation n.d.
85. Collegly 1931; Niagara Mohawk Power Corporation n.d., correspondence file 2-T7-H4, and 2-T7-H4: Buffalo Niagara & Eastern Power Corp. 1931 [plans].
86. Niagara Mohawk Power Corporation n.d., and 1989b [plans].
87. White 1918: 1028-29.
88. White 1918; Niagara Mohawk Power Corporation n.d.
89. Ibid.
90. White 1918, 1927; Niagara Mohawk Power Corporation n.d.
91. Ibid.
92. Niagara Mohawk Power Corporation n.d., and correspondence file 2-T7-H4.
93. Niagara Mohawk Power Corporation n.d.
94. Niagara Mohawk Power Corporation, file "Surge Tank-Corresp," and 1989a [plans].
95. Personal communication, Robert Easterly; Niagara Mohawk Power Corporation n.d., and 1989b [plans].

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96. *Electrical World* 1906; Howard 1951: 145, 153; Niagara Mohawk Power Corporation n.d., and 2-T7-H4; Murray and Orrok 1919 [plans].
97. Niagara Mohawk Power Corporation n.d.
98. Ibid.
99. Ibid.
100. Ibid; White 1918.
101. Niagara Mohawk Power Corporation n.d.
102. Ibid.

Part III - Sources of Information

Original Drawings

Niagara Mohawk Power Corporation has over 1600 historic or current plans and drawings, the great majority of them on microfilm, at its headquarters. These materials include many contractor or consulting engineer plans prepared for original construction of the dam, headworks, pipelines, powerhouses, and substation, with a number of plans showing proposed features or equipment not installed. The earliest drawings date from 1899. Most drawings are coded with a system introduced after many of them were originally prepared. The system is based on different sites, electrical, hydraulic, and structural components. Drawings used for this documentation, with their codes, are listed below. Other drawings are listed for HAER Nos. NY-155-A and NY-155-B. For access, contact:

Environmental Quality Services
Niagara Mohawk Power Corporation
300 Erie Boulevard West
Syracuse, NY 13202

ATTN (1993): Scott D. Shupe, Environmental Analyst, tel. 315/428-6616

No Codes or Illegible Codes

Niagara Mohawk Power Corporation

- 1989a Constructed West Canada Creek Project. Trenton Development. Intake, Pipelines and Surge Tank. Profiles, Section and Elevation. License Amendment Exhibit F, Sheet 5A.
- 1989b Constructed West Canada Creek Project. Trenton Development. General Plan - Dam and Spillway. Plan, Elevations and Sections. License Amendment Exhibit F, Sheet 4B.
- 1989c Constructed West Canada Creek Project. Trenton Development. Detail Map. License Amendment Exhibit G, Sheet 5A.

2-T7-H0: General

Brackinridge, W.A.

- 1901 Utica Electric Light and Power Company. Map showing location of Dam, Pipeline and Power House. No. R-106.

2-T7-H2: Dams & Appurtenances, Dikes

Brackinridge, W.A.

- 1899a Utica Electric Light and Power Company. Vertical Section of Dam showing Waste and Motor Pipes. No. A-6
- 1899b Utica Electric Light and Power Company. Horizontal Section of Dam showing Waste and Motor Pipes. No. R5.
- 1899c Utica Electric Light and Power Company. Map showing location of Dam. No. R12.

2-T7-H3: Intake (Sluice Gates)

Utica Gas & Electric Company

n.d. Trenton Falls Extension. Profile of 12' Dia. Pipe Line. No. S-90.

2-T7-H4: Pipe Line, Tunnels, & Canal

Buffalo Niagara & Eastern Power Corp./Utica Gas & Electric Co.

1931 Trenton Falls Plant. Details of House for Pipe Line Air Valves. No. 10763.

Murray, Thomas E./George A. Orrick

1919 Trenton Falls Extension. Proposed High Level Intake and Connecting Pipe. No. 5994[?].

2-T7-H13: Powerhouse - Superstructure

Anonymous

c1942-5a Trenton Falls Dam Building Inspection/General Plan.

c1942-5b Trenton Falls [Powerhouses] Building Inspection/General Plan.

2-T7-H21: Turbines & Governors

I.P. Morris Co.

1900a Utica Electric Light & Power Co./1700 HP Turbine Wheels (proposed). No. 5672.

1900b Utica Electric Light & Power Co./1700 HP Turbine Wheels (proposed). No. 5686.

1900c General Arrangement of Governor/1700 HP Turbine/Utica Electric Light & Power Co. No. 5751.

1900d General Arrangement. 1700 HP Turbines, for Utica Electric Power & Light Co. No. 5753. [also a 1901 version, 2 copies]

1900e Wheel and Distributor/100 HP Turbine for Utica Electric Light & Power Co. No. 5864.

1900f Casing and Cover/100 HP Turbine for Utica Electric Light & Power Co. No. 5865.

1900g General Arrangement/100 HP Turbine for Utica Electric Light & Power Co. No. 5892.

Pelton Water Wheel Co.

1899 Proposed Arrangement of Pelton Water Wheels for the Utica Electric Power & Light Co. [no no.]

Platt Iron Works

1917 Trenton Falls/Sketch of 57" Wheel Setting/Utica Gas & Electric Co. No. 60312.

2-T7-M5: General Survey and Maps

Anonymous

1935

Trenton Falls Hydro-Plant Location Map of Buildings and Structures/ Oct. 15, 1935. Dwg. No. 21787.

Historic Views

There are few available photographs before the construction of the new powerhouse. Some appear in *Electrical World* 1906, and a small number are in private hands (see HAER No. NY-155-A). Niagara Mohawk Power Corporation has over 1000 historic views at its headquarters, in several collections, including a small number of pre-1917 views. Aside from published views in White 1918, new powerhouse construction photographs appear rare, but after c1919-20 the Niagara Mohawk collection provides a very full record of changes made at the station. For access, see Original Drawings, above.

Interviews

Many Niagara Mohawk Power Corporation employees provided valuable information during research for this documentation from March to May 1993. At the Syracuse headquarters, engineers, designers, and analysts included Paul Bernhardt, Robert Easterly, Joseph Flood, Samuel Hirschay, Jacob Niziol, Gary Schoonmaker, Robert Shantis, Scott Shupe, and Joseph Vian. Edward Cooney, Harbor Point control supervisor, and past or present Trenton Falls Station operators George Distefanis, Robert Dolan, Robert Jones, and Wayne Richard shared years of personal station management experience.

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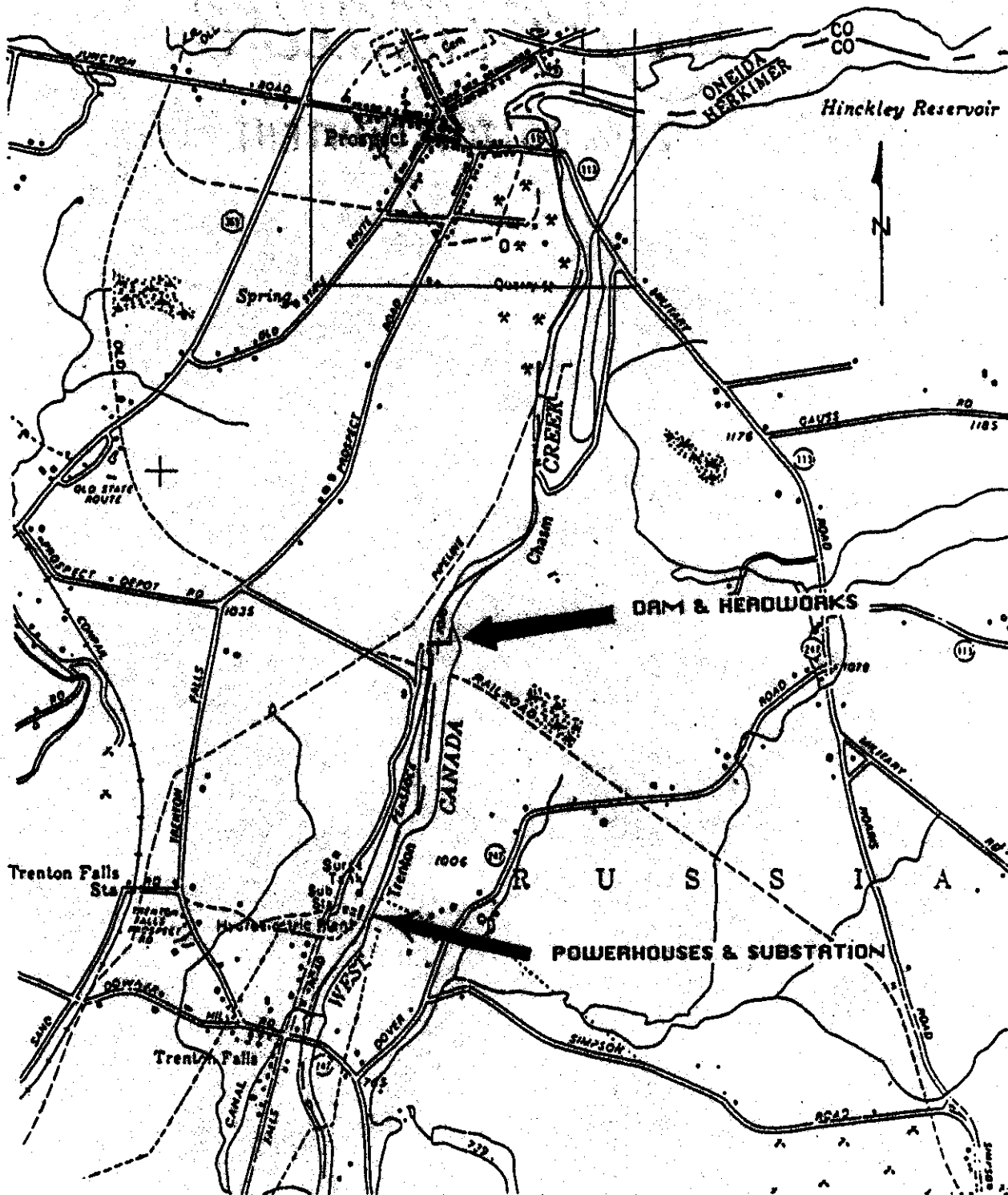
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More intensive use of available plans and historic views might reveal additional structural or station history details, presumably minor in nature. Further interviews with past and present station operators would yield useful information on equipment performance or hydraulic problems since at least c1945, as well as first-hand perspectives on operator staffing and organization patterns.

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TRENTON FALLS HYDROELECTRIC STATION ON WEST CANADA CREEK
(base map: Remsen U.S. Geological Survey 7.5-Minute Quadrangle Sheet)